NSW DEPARTMENT OF
PRIMARY INDUSTRIES

SOILpak – southern dryland farmers - Readers' Note

This document is part of a larger publication. The remaining parts and full version of the publication can be found at:

http://www.dpi.nsw.gov.au/agriculture/resources/soils/guides/soilpak/south-dryland

Updated versions of this document can also be found at the above web address.

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[A] NSW Agriculture, [B] CSIRO, [C] DLWC

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Appendix 2. Further reading

The following is a selection of publications that may be useful as further reading. It is not a complete bibliography of soils literature.

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Appendix 3. Useful terms

A, A1, AP HORIZON: see soil profile.

ADSORBED: gathered on a surface; in soil, cations gather on clay surfaces due to the different electrical charge between the cations and the soil surface.

AEROBIC: soil conditions in which there is adequate oxygen in the soil air and water. This condition is favourable for root growth and for those organisms that carry out processes beneficial to plant nutrition and soil structure.

AGGREGATE: a natural soil unit made up of a group of peds; the peds comprising the aggregate are bound together more firmly than the aggregate is to other aggregates. (Therefore the aggregate is recognisable as a unit.)

ALLUVIAL SOIL: a young soil developing in recently deposited alluvium; any layers visible are usually the result of successive deposits rather than soil horizons.

ALLUVIUM: unconsolidated layers of sand, silt and clay deposited by water flow, typically on floodplains.

ANAEROBIC: soil condition where there is a lack of oxygen, usually due to waterlogging. Roots become stressed and harmful micro-organisms are favoured.

ANION: chemical name for an ion with a negative charge, for example, NO_3^- and SO_4^{2-} (see *Cations*).

AQUIFER: a water-bearing layer below the soil capable of yielding water to bores and springs.

AUSTRALIAN SOIL CLASSIFICATION (ASC): the current classification for Australian soils; replaces 'Great Soil Groups' and 'The Factual Key'(Northcote). The ASC has a number of unusual terms that are classical Latin or Greek. 'Sols' means soil, so it appears at the end of each soil type, for example, chromosols. The first part of the word is a characteristic of that particular soil type, for example, 'chromo' means colours; these soils usually have a dark topsoil and a red or yellow subsoil.

Chromo means colour; Sodo means sodium; Verto means vertical cracks; Kando means kandite clay

B HORIZON: see *Soil profile*.

BED: a raised flat-topped ridge of soil for growing crops on wet country.

BIOLOGICAL DRILLING: using tap-rooted plants to penetrate through a hard soil layer or into a hard subsoil; when the roots die the channels they have made are available for following crops.

BIOLOGICAL FERTILITY: see *Fertility*.

BLEACHED: a pale soil colour, often indicating poor drainage.

BULK DENSITY: a measure of dry soil compactness. More compact soils (higher bulk density) have less airspace in them.

C HORIZON: see *Soil profile*.

CA:MG RATIO: ratio of exchangeable calcium to exchangeable magnesium. The balance of Ca:Mg used to be considered important in plant nutrition. However, further research has shown no differences in plant growth over a wide range of Ca:Mg rations. A low ration (less than 2) may aggravate the tendency of a sodic soil to disperse.

CALCAREOUS: a soil layer that naturally contains significant quantities of lime.

CALCIUM: an essential plant nutrient; a cation that promotes good soil structure.

CATION: an ion with a positive charge, for example, Ca^{2+} or NH_4^+.

CATION EXCHANGE CAPACITY (CEC): a measure of a soil's ability to store cations. It is influenced by the amount of clay and organic matter in the soil. CEC values are expressed as centimoles of positive charge per kilogram of soil (cmol(+)/kg).

CAPILLARY RISE: the upward movement of water from a watertable caused by the molecular attraction between soil particles and the water. This water movement may carry salt into the crop root zone from a shallow watertable.

CHEMICAL FERTILITY: see *Fertility*.

CHROMOSOL (ASC): a texture contrast soil in which the top 0.2 m of the B horizon is neither strongly acid nor sodic.

CLAY: 1. soil particles smaller than 0.002 mm in (effective) diameter. These particles have very large surface areas and negatively charged surfaces, so they are important in water storage and cation exchange capacity. A number of chemicals may form clay-sized particles in the soil. Kaolin clay does not expand much when wetted, but smectite (a clay formed mainly from basalt) is highly expansive. Expansive clays self-mulch at the surface, expand to store a lot of water, and are responsible for the soil movement that cracks buildings. **2.** a soil with more than 35% clay content, these soils are plastic and cohesive when wet.

CLOD: a large coherent lump of soil produced by cultivation. see *Aggregate* and *Ped*.

COLLOID: material consisting of very finely divided particles that as a result have a very large surface area per unit volume and are very reactive. Clay and humus are colloids. Such material represents the finest particles removed by erosion events, since it tends to remain in suspension.

COMPACTION: the compression of the soil or a soil layer into a smaller volume, thus reducing its air and water content. see *Smearing*.

CONTROLLED TRAFFIC: the confinement of field traffic wheels to the same pathways for all tillage and spraying operations.

CONVENTIONAL TILLAGE: describes traditional farming systems where tillage is the main method used for seedbed preparation and presowing weed control. This normally involves three or more tillage operations.

CRACKING CLAYS: black, grey or brown (more rarely red) clay soils that are distinguished by seasonal cracking and a lack of distinct horizons. see *Vertosol*.

CROP WATER USE: the water used by a crop from sowing to harvest. It includes evaporation from the soil as well as transpiration through the leaves. Usually expressed as mm of water.

CRUSTING: occurs when the soil surface 'runs' together when wet and then packs down into a hard layer and is impermeable when dry. A crust is about 5 to 10 mm thick and can be lifted off the underlying soil when dry.

DEEP TILLAGE: any tillage deeper than that needed to produce loose soil for a seedbed or deeper than that needed to kill weeds. The usual purpose of deep tillage is to loosen a hard subsoil or a tillage and traffic-induced compaction layer.

DENITRIFICATION: the process by which soil microbes convert soil nitrate to nitrogen or nitrous oxides. These are gases that are unavailable to plants and are eventually returned to the atmosphere.

DEPOSITION: the settling out of soil particles transported to the site by wind or water.

DISCHARGE AREA: an area where underground water is released at the soil surface

DISPERSION: breakdown of the soil into individual sand silt and clay particles. May occur on wetting when the soil has > 6% exchangeable sodium.

DRYLAND SALINITY: all non-irrigated areas showing symptoms of salinity.

DRY SCALD: occurs on red duplex soils in arid areas where wind erosion removes the topsoil exposing the sodic clay subsoil. A dry scald has a hard, bare surface.

DUPLEX SOIL: a soil that has a sharp change in soil texture (clay content) between the A and B horizons. see *Gradational, Uniform*.

ELECTRICAL CONDUCTIVITY (EC): a measure of the ability of a suspension of soil in water, or of water extracted from the soil, to transmit an electric current. It is a measurement of salts that may dissolve in the soil water, and hence a measure of salinity; reported in units of deciSiemens/metre (dS/m).

ELECTROLYTE: salts in a water solution.

ESP: see *Exchangeable sodium percentage*.

EVAPORATION: the process by which water changes from a liquid to a vapour state and enters the atmosphere.

EVAPOTRANSPIRATION: the sum of water lost from the soil–plant system by evaporation from the soil and transpiration from living plants.

EXCHANGE CAPACITY: the ability of the soil clay and humus to hold ions on charged surfaces. Negatively charged surfaces (cation exchange sites) hold cations, which are positively charged. Positively charged surfaces hold anions, which are negatively charged. This storage capacity is measured in centimoles of charge per kg of soil (cmol(+)/kg and cmol(-)/kg).

EXCHANGEABLE CATIONS: positively charged ions held weakly on the surface of negatively charged soil particles and readily exchanged with other cations in soil water. The balance of exchangeable cations affects soil structural stability. Some important plant nutrients are held as exchangeable cations, and so are less prone to leaching loss.

EXCHANGEABLE SODIUM PERCENTAGE: the number of exchangeable sodium ions as a percentage of all exchangeable cations held on the soil. An exchangeable sodium % greater than 6% promotes dispersion.

FERTILITY: the capacity of the soil to support plant growth. It has three components; chemical, biological and physical fertility.

A soil with good chemical fertility can supply adequate nutrients for plant growth through the growing season while ensuring that plant uptake of potentially toxic elements is below health standards.

A soil with good biological fertility has high numbers and high diversity of soil organisms. This promotes stubble breakdown and suppresses the activity of pathogens that attack plant roots.

A soil with good physical fertility can adsorb a high proportion of the rain that falls and store it for plant use, while ensuring that there is enough air movement in the soil to enable roots and beneficial organisms to respire.

FLOCCULATION: clustering of clay particles into small groups; the opposite of dispersion. Occurs when gypsum is applied to dispersive soils.

FRIABLE: easily crumbles in to peds (has natural well structured aggregates).

GILGAI: a natural surface of mounds (‘puffs’) and hollows found in many swelling clay soils, for example, vertosols.

GRADATIONAL SOIL: a soil profile with a steady increase in clay content with depth.

GYPSUM: calcium sulfate, a common mineral used to reduce dispersion. Available as a by-product of fertiliser manufacture or from mining old lakebed deposits.

HARDSETTING: occurs when a layer of soil, not necessarily at the surface, ‘melts’ together when very wet and then sets hard when dry.

HORIZON: a layer of soil in the soil profile differing from the soil above or below in its colour, texture or structure. Horizons form as the result of environmental factors acting on the soil.

HUMUS: large organic compounds produced by the decomposition of onceliving material to the point where the original structure of the organic matter can no longer be seen.

IMPERMEABLE: transmits no water or air.

INFILTRATION: movement of water into the soil surface.

ION: atom or molecule carrying an electrical charge.

KANDOSOL (ASC): a soil that lacks an abrupt texture change to the massive or only weakly structured B horizon, that has a B2 horizon clay content exceeding 15%, and that is not calcareous throughout.

KUROSOL (ASC): texture contrast soils with the upper part of the B2 horizon strongly acid.

LEACHING: carrying dissolved material out of a soil layer.

LEVEE SOIL: alluvium deposited 'recently' along the line of a watercourse. A levee is higher than the surrounding plains.

LIME: calcium carbonate, a slowly soluble source of calcium in the soil, often found as fine particles or as nodules in the subsoil. Finely ground lime (aglime) is used to raise the pH of acid soils.

MACROPORE: a large soil pore (effective diameter greater than 0.05 mm). These pores are made by soil cracking, earthworms and roots. They rapidly transmit water after rain and drain quickly to admit air to the soil; they indicate good soil structure.

MAGNESIUM: an essential plant nutrient; a cation that promotes dispersion in clay soils (but less important than sodium at doing this).

MASSIVE: a soil structure largely lacking natural lines of weakness or visible structure.

MICROPORE: a soil pore with a diameter less than 0.05 mm. The numbers of these in the soil is influenced by the texture. They store soil water.

MINERALISATION: the processes by which soil bacteria convert organic forms of nutrient into plant-available forms, for example, nitrogen to ammonium. see *Nitrification*.

MINIMUM TILLAGE: a tillage system relying on cultivation near sowing for seedbed preparation only. Fallow is eliminated and weed control is achieved by rotation and herbicide use. see *No-till*.

MOTTLED: many subsoils have small blotches of differing colours, indicating that these soils have been subject to intermittent waterlogging.

MYCORRHIZA: a fungal growth often found around plant roots; it helps plants to absorb soil nutrients.

NITRIFICATION: the processes by which soil bacteria convert ammonium to nitrate.

NITROGEN FIXATION: the process of converting atmospheric nitrogen into compounds that eventually become available to plants. One such process is the conversion of nitrogen by rhizobia in the nodules on legume roots into plant-available ammonium.

NODULE: 1. a discrete lump on the root of a legume such as clover, lucerne or lupins. **2.** a discrete small lump in the soil. Lime, iron and manganese all are capable of being leached from near the surface and later precipitated deeper in the soil. Focal points of precipitation are added to each season, so the nodules grow as concentric layers.

NO-TILL: a cropping system that uses cultivation only at sowing. Fallow is eliminated and weed control is achieved by rotation and herbicide use. Careful management is needed to ensure that good soil structure is maintained so that an adequate seedbed can be obtained by the sowing tillage.

ORGANIC CARBON: a measure of the soil organic matter level. Carbon content rather than organic matter is measured in soil tests, and the results are therefore expressed as organic carbon. Multiply the total organic carbon by 1.75 to obtain an estimate of organic matter, or, if the Walkley-Black method was used, multiply by 2.3.

ORGANIC MATTER: dead plant and animal material.

PAN: a dense soil layer that restricts the entry of roots, water and air. When caused by tillage it is called a plough pan.

PED: a natural fragment of soil separated from adjoining clusters by surfaces of weakness.

PERCHED WATERTABLE: temporary saturation of a layer in the soil after heavy rainfall. Occurs in the surface soil of duplex soils immediately above a clay rich B horizon and is separated from the true watertable by the less permeable B horizon.

PERCOLATION: movement of water through the soil.

PERMANENT BEDS: a cropping system where the crop is grown in slightly raised cultivated beds separated by furrows. The farm machinery and bed widths are adjusted so that the tractor and implement wheels always run in the furrows. The furrows become compacted and smooth, reducing power losses and improving traction. Compaction of the cropped area is eliminated, and waterlogging may be reduced, as water can more readily drain off the paddock along the furrows.

PERMEABILITY: the ability of the soil to transmit water and air.

PH: the acidity of a soil is measured as pH units on a scale of 1 to 14, with 1 being most acid and 14 most alkaline. pH 7 is neutral. Most field pH kits and some labs use water-based methods. However, more reliable results are obtained when the pH is measured in a mixture of soil in calcium chloride solution (pH $CaCl_2$). In $CaCl_2$ pH values are about 0.5 to 0.8 units lower than in water.

PH BUFFERING CAPACITY: the resistance of the soil to change in soil pH.

PHYSICAL FERTILITY: see *Fertility*.

PIEZOMETER: a small-diameter cased borehole used to measure the pressure level of ground water in aquifers. Useful in estimating the effectiveness of recharge control strategies.

PLANT AVAILABLE WATER CAPACITY (PAWC): the maximum amount of water that a soil can store and later release for plant growth; it is measured in millimetres of water stored in the whole root zone.

PLANTBACK PERIOD: the waiting period between using a herbicide and the planting of a susceptible crop.

PLASTIC LIMIT: the water content at which the soil passes from a solid to a plastic state—the water content at which the soil can be remoulded (is plastic). It is determined by rolling out a bead of soil with the fingers. Cultivation should only be carried out when the soil is drier than the plastic limit.

PLASTIC: capable of being moulded.

PLATY CLODS: soil aggregates with greater horizontal than vertical dimensions. Often an indication of compaction.

PORE: channel or cavity in the soil.

POROSITY: the degree to which a soil is permeated with pores; the fraction of the soil volume made up of pores, but also the size and shape of the pores and the degree of connection between them.

PROFILE: a vertical section of a soil through all its horizons and extending to parent material. Also see *Soil Profile*.

PUGGING DAMAGE: damage to soil structure caused by stock trampling wet soil.

RECHARGE AREA: area where surface water from rain or creeks penetrates the soil and adds water to the groundwater system.

RED EARTH: red soils with a gradational texture profile. Now classed as Kandosols (ASC).

RED BROWN EARTH: red soils with hardsetting topsoils changing abruptly to heavy clay subsoils. Most would now be classed as sodosols or chromosols (ASC).

RHIZOBIUM: nitrogen-fixing bacteria that can live symbiotically in nodules on legume roots.

ROOT ZONE: the depth of soil in which the majority of live plant roots are located.

SALINE SCALD: a bare, dry, salt-affected area resulting from topsoil loss exposing a naturally saline subsoil.

SALINE SEEP: a bare, damp, salt-affected area resulting from rising saline ground water

SALINITY: an excess of salt (usually sodium chloride) in the soil water, sufficient to restrict plant growth.

SAND: mineral soil particles between 2 mm and 0.02 mm in diameter. Fine sand is 0.02 to 0.2 mm; coarse sand is 0.2 to 2 mm.

SCALD: a bare area, inhospitable to plants because of its high clay content and either sodicity or salinity.

SEDIMENTS: layers of clay, silt, or sand deposited by wind or water streams.

SELF-MULCHING: the ability of the surface of some clay soils to swell when wet and to shrink and fragment into small aggregates after drying.

SILT: mineral soil particles between 0.002 and 0.02 mm in diameter. They possess neither the good drainage of sands nor the chemical activity of clay; soils rich in silt are the most difficult to manage.

SLAKING: collapse of aggregates to microaggregates in wetted soil due to the swelling of clay and the escape of trapped air.

SLICKENSIDES: natural shiny surfaces sometimes found on clay soils. They result from the frequent shrink-swell cycles in expansive clays.

SLUMPING: cultivated soil tends to slump or collapse into a continuous mass after rain. This layer can then set hard and reduce infiltration.

SMEARING: the realignment of clay particles by mechanical disturbance when wet. Smearing reduces both porosity and the connectiveness of soil pores, and so greatly reduces infiltration.

SODIC: soils with greater than 6% exchangeable sodium as a proportion of the CEC.

SODOSOL (ASC): texture contrast soils that have naturally sodic clay B horizons and that are not strongly acidic in the upper 0.2 m of the B2 horizon.

SOIL EVAPORATION: water evaporated from the soil surface, as distinct from water lost by plants. Soil evaporation from wet soil is high until the crop or pasture grows to completely cover the ground. Evaporation from the soil is much slower once the surface is dry.

SOIL PROFILE: the vertical sequence of layers in the soil is identified by letters of the alphabet. The topmost layer, called the A horizon, is the zone from which material is leached. It may comprise a series of sublayers. There may be a distinct layer to the depth of cultivation. This is the Ap or plough layer. The A horizon usually has a topmost layer darkened by the presence of organic matter. This is designated the A1 horizon. In texture contrast soils the base of the A horizon may be paler than the soil above or below. This paler layer is designated as the A2 horizon.

Below the A horizon is a zone of accumulation of material such as clay, iron or lime leached from above. This is designated the B horizon. The B horizon is usually richer in clay and more strongly coloured than the layers above or below. Layers within the B horizon are also numbered.

Where the soil has developed from the underlying alluvium or rock, the weathered parent material is called the C horizon.

STUBBLE MULCHING: cultivation techniques that leave most of the stubble on the soil surface.

STRUCTURE: (of soil) the way in which soil particles are arranged into larger units, and the nature of the spaces between the soil units. Structure has three facets: form, resiliency, and stability.

STRUCTURAL FORM: the arrangement of soil material (sand, clay, organic matter) into larger units called peds and aggregates, and the size and continuity of the pore spaces between them. It includes the shape and size of the peds, the nature of their faces, their porosity and their friability.

STRUCTURAL RESILIENCY: the ability of the soil to revert to a good structural form after cultivation.

STRUCTURAL STABILITY: the ability of the soil to retain its structural form despite the destructive impact of raindrops, cultivation, and stock trampling.

SYMBIOSIS: a close, mutually beneficial relationship between different species. An example is the infection of legume roots by rhizobium bacteria, where the bacteria use plant sugars for growth and in turn fix atmospheric nitrogen which plants use.

TEXTURE: the sand, silt and clay content of the soil. It is determined by the behaviour of a small handful of soil when moistened and kneaded into a ball and then pressed out between thumb and forefinger.

TEXTURE CONTRAST: a sharp increase in clay content over a distance of 2 to 5 cm. See Duplex Soil.

TRANSPIRATION: the process by which plants lose water from their leaves.

UNIFORM SOIL: a soil in which the texture changes very little with depth. Horizons may be visible due to changes in organic matter levels or iron content. Vertosols and dune sands are examples of uniform soils.

VERTOSOL (ASC): soils with greater than 35% clay at all depths, which crack deeply on drying.

WATERTABLE: the upper surface of the groundwater pool in which the soil and its underlying sediments are saturated with water. see Perched watertable.

WATERLOGGED: a soil in which the pores are so filled with water that air movement is reduced to the point where the oxygen supply is insufficient for full root activity.

WATER USE EFFICIENCY: a measure of the conversion of rainfall into saleable plant products, for example, kg of grain harvested for each mm of growing season rainfall.

WEATHERING: the continuing process whereby mineral soil and the underlying rocks are broken down by a combination of water, temperature change and chemical and biological attack. The temperature and rainfall conditions under which the soil forms have as big an influence on the final soil type as does the type of parent rock. The weathering process releases plant nutrients.

ZERO TILLAGE: see *No-till*.

Appendix 4. Soil description sheets

To record soil results and information for each paddock.

1. FARM AND PADDOCK INFORMATION

Farm details

Farmer:	**Property:**
Paddock:	**Reasons:**
Inspected by:	**Date:**

Sketch site: Sketch map of site:

Paddock history

	Year	Crop or pasture	Lime (t/ha)	Gypsum (t/ha)	Stubble treatment (retain or burn)	Cultivation technique (number of workings,wide or narrow points)
This year						
last year–2						
previous–3						
previous–4						
previous–5						

Profile

0

10

20

30

40

50

60

70

80

90

100

+

2. SURFACE CONDITION	Poor area	Good area
% ground cover		
Pugging: a heavily compacted area that waterlogs		
Crusting: bare soil that forms a hard surface about 0.5–1cm thick, reducing infiltration		
Hardsetting: when the topsoil sets hard and cannot be penetrated		
Cloddiness: lumps of soil brought to the surface by cultivation		
Slumping: when the clod surface 'runs' together, forming a lumpy crust		

3. SOIL FEATURES

	Depth (cm)	Texture	Colour	Aggregate size (cm)	Aggregate shape	Fabric consistency	Slaking and dispersion	pH (water)
Topsoil								
Sub-surface								
Subsoil								

4. CHEMICAL TESTS (Refer to Chapter C5, Chemical soil tests)

Depth(cm)	pH $CaCl_2$	Aluminimum %	Organic Matter %	Soil nitrate NO_3^-	Salt EC_e dS/m	Sodium ESP %	Ca:Mg ratio	Other

pH	☐ acidic <5	☐ neutral 7	☐ alkaline > 8
Al	☐ < 5% satisfactory	☐ 5%–15%	☐ > 15% high
OM	☐ low < 1	☐ moderate 1–2	☐ high > 2
EC_e	☐ low < 2 dS/m	☐ moderate 2–8 dS/m	☐ high > 8 dS/m
ESP	☐ low < 6	☐ moderate 6–15 (apply gypsum)	☐ high > 15
Ca:Mg	☐ poor < 1	☐ low 1–2	☐ satisfactory > 2

Other comments:

5. MANAGEMENT:

Comments on structure:

Compaction layer: ☐ Present: at what depth? ☐ Absent

Broad soil type: ☐ Cracking clay ☐ Earth ☐ Texture contrast red or bright yellow subsoil

Management options:
(consult your SOILpak or speak to an agonomist or catchment manager)